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THE OPERATION OF AN AMERICAN OR RAPID WATER FILTRATION PLANT FOR TWENTY YEARS AT YORK, PA.[1]

By James M. Caird[2]

There are few water systems which combine storage and stream flow regulation, reforesting, pumping, sterilization, aeration, sedimentation, coagulation and filtration. These agencies are employed by the York Water Company, which supplies water to York, Pa., a city located in the south central part of the state, having a population of about 55,000.

The water supply is obtained from the south branch of the Codorous Creek, the pumping station being located about four miles from the center of the city. The creek, with a drainage area of about 100 square miles above the pumping station, is subject to severe floods, and at times is somewhat polluted. The water always contains some color and turbidity.

In 1912 the storage or stream-flow regulating reservoir was placed in service, having a capacity of 1,000,000,000 gallons and a water surface area of 170 acres. In order to protect this reservoir 570 acres of land were purchased and 300,000 trees planted on the watershed.

The pumping station is equipped with three high-duty steam pumps, one of 8,000,000 and two of 5,000,000 gallons capacity, by which the water is lifted 308 feet for delivery and forced through a 24-inch main to an aerator about 2½ miles from the pumping station.

In October, 1910, a hypochlorite plant was installed at the pumping station, and since that time all water has been treated with the sterilizing reagent before aeration, with the results shown in table 1. These results show that the sterilization reduces the bacteria in the creek water 97.52 per cent before the water enters the sedimentation basins. During this same period 84.92 per cent of the 1 cc. samples of creek water and 14.39 per cent of the samples of sterilized water

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[1] Discussion of this paper is requested, and should be sent to the Editor.

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TABLE 1

Bacterial counts per cubic centimeter (gelatin) of creek water and of water after different stages of treatment, percentage of positive presumptive tests for B. coli, and typhoid fever death rate per 100,000 population

YEAR	CREEK			AERATED			SETTLED			FILTERED			TAP, AVERAGE	PERCENTAGE PRESUMPTIVE TESTS FOR B. COLI 1 CC.					TYPHOID DEATH RATE	TYPHOID CASES
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average		Creek	Aerated	Settled	Filtered	Tap		
1899			5,543	19,900	2,400	5,543	132,000	1,000	1,166	700	5	38		100	100	100	2	0	84.6	131
1901							480	120	257	60	6	18		100	100	100	2	0	41.5	105
1902			1,975	2,700	1,150	1,975	1,080	190	545	10	2	4		100	100	80	2	0	29.7	87
1903			2,090	5,380	680	2,090	1,170	62	413	15	1	3	6	100	100	45	0	0	11.8	39
1904			2,167	3,950	290	2,167	785	102	276	4	1	2	2	100	100	40	2	0	32.6	29
1905			1,463	2,190	880	1,463	890	200	442	6	1	1	1	100	100	49	0	0	17.8	71
1906			969	1,600	686	969	334	175	233	4	1	2	2	87	87	33	17	0	15.3	79
1907			7,485	21,500	2,080	7,485	3,233	750	1,410	29	1	9	13	85	85	45	0	0	30.7	96
1908			620	760	510	620	690	220	413	110	3	20	29	90	90	90	2	0	15.3	45
1909			6,618	111,300	260	6,618	22,950	33	1,272	1,300	1	41	26	92	92	69	2	0	15.3	66
1910			10,715	62,000	57	8,380	30,100	1	2,553	1,000	1	84	42	93	72	43	0	0	11.2	74
1911	120,000	3,245	42,367	1,900	1	129	126,500	1	2,889	1,600	1	15	23	92	12	11	0	0	24.6	102*
1912	6,450	850	3,650	12,250	19	473	29,880	8	1,572	2,240	1	70	54	87	11	6	0	0	8.9	54
1913	53,600	980	14,191	2,310	20	190	171,000	30	1,420	1,420	1	49	4	73	24	19	0	0	8.9	86
1914	59,500	485	7,624	19,050	30	469	29,200	30	1,500	880	1	23	13	76	17	12	1	0	8.9	94
1915	44,300	580	6,694	4,400	25	260	129,000	6	6,520	2,290	1	83	32	85	13	9	0	0	19.2	170†
1916	72,000	600	7,812	11,300	20	271	235,200	20	6,729	170	1	8	16	90	14	12	0	0	15.3	64
1917	38,700	515	10,505	4,650	26	212	35,750	20	1,667	1,458	1	30	17	100	16	9	0	0	13.4	46
1918	51,000	570	9,351	32,500	20	485	3,650	10	208	209	1	4	2	77	9	9	0	0	11.4	64‡
Ave..	55,694	978	7,880	17,758	509	2,211	50,205	157	1,657	711	2	27	18	91	60	41	2	0	22.6	79

* Includes 34 cases due to milk.

† Includes 60 cases due to ice cream.

‡ Includes 13 cases due to milk.

Note: The figures for aeration also cover the sterilization of the water at the pumping station since October, 1910.

contained B. coli. This treatment therefore reduces this organism 83.07 per cent. The average amount of hypochlorite used was 6.52 pounds per million gallons of water.

There has also been installed at the pumping station sulphate of alumina tanks, so that any time it should become necessary to pump water containing a turbidity of over 500 parts per million, some coagulant could be added, thereby materially assisting sedimentation in the large basins, and relieving the load from the filters. The capacity of the sedimentation basins is such that up to the present time it has not been necessary to operate the pumps during periods of high turbidity.

After aeration the water flows to two brick-lined sedimentation basins which, having a combined capacity of about 40,000,000 gallons, afford from 10 to 14 days sedimentation of the water before it passes to the filters. This water, even after treatment with the sterilizing agent and thoroughly saturated with oxygen by aeration, supports algae growths. The water develops a strong "mouldy" odor and taste, the principal organisms present being oscillaria and anabaena. At these times considerable trouble is experienced in operating the filters, due to the rapid clogging of the sand beds. This causes the filters to require frequent washings, and as filtered water is used in washing and has to be pumped, the operating expenses are thereby increased.

At these times the water in the basins is treated with copper sulphate and after a few hours normal conditions are restored. The bacterial content of the water increases greatly after the copper sulphate treatments.

Table 1 shows that the bacteria were reduced 25.1 per cent by sedimentation.

During the twelve years before the sterilizing reagent was used, the basins reduced the bacteria 75.9 per cent; while during the eight years that the water has been sterilized before entering the basins the bacteria increased from an average of 314 to 3748 per cc., or 1093 per cent. This increase is due to a secondary growth and also the growth which follows the copper sulphate treatments, and is not unusual in a treated stored water.

During the 19 years the basins reduced the B. coli at least 31.4 per cent. During the 11 years before the sterilizing reagent was used, the basins reduced the B. coli 32.5 per cent while during the 8 years that the sterilizing reagent has been used this organism has been reduced 23.4 per cent.

Table 2 shows that the basins reduce the turbidity 62.4 per cent and produce a very uniform water for filtration.

The storage of this water in the sedimentation basins exposed to air and light reduces the color 41.9 per cent.

The sedimentation basins are drained and cleaned about every second year.

TABLE 2

Color and turbidity of creek water and water after various stages of treatment, sulphate of alumina used in grains per gallon, and percentage of water used for wash

YEAR	TURBIDITY								ALUM	WASH WATER	COLOR							
	Creek Average	Aerated			Settled			Filtered Average			Creek Average	Aerated			Settled			Filtered Average
		Maximum	Minimum	Average	Maximum	Minimum	Average					Maximum	Minimum	Average	Maximum	Minimum	Average	
1899					12	8	10	0	1.62	3.00					20	7	17	0
1901					100	7	39	0		3.90								
1902		500	12	39	50	35	41	0	0.50	2.57					40	12	25	0
1903	45	65	16	45	15	7	9	0	0.89	2.26		55	30	42	35	25	32	0
1904	43	60	35	43	16	8	11	0	1.01	1.84		45	20	33	28	15	20	0
1905	82	140	50	82	28	7	13	0	1.00	2.60		45	25	35	18	13	16	0
1906	31	50	26	31	13	8	10	0	1.02	3.60		22	18	19	50	15	27	0
1907	141	800	30	141	13	8	11	0	1.19	2.27		70	15	31	30	12	18	0
1908	23	35	16	23	16	6	10	0	1.24	2.56		28	15	20	22	15	18	0
1909	28	40	22	28	10	7	9	0	1.25	3.60								
1910									1.41	2.78								
1911	116	3,000	8	126	180	7	31	0	0.66	2.05					20	6	12	0
1912	78	5,000	10	147	500	15	46	0	0.73	2.14					11	7	10	0
1913	71	4,000	10	85	160	10	41	0	0.65	2.13		40	18	31	12	8	10	0
1914	67	1,000	20	75	200	12	39	0	0.68	2.27		35	12	25	15	9	11	0
1915	115	640	10	92	240	13	49	0	0.68	2.24		30	20	26	20	3	11	0
1916	61	400	15	51	140	10	28	0	0.64	2.04	29	35	20	26	15	8	10	0
1917	122	360	10	97	280	10	56	0	0.61	2.02	23	30	12	21	13	7	9	0
1918	74	560	10	68	240	10	44	0	0.55	1.99	17	18	12	16	20	5	9	0
Average..	73	1,041	19	73	123	11	28	0	0.91	2.54	23	38	18	27	23	10	16	0

The water flows from the sedimentation basin to the filters, and the sulphate of alumina which is used as a coagulant is pumped into this water. The coagulant feeding device is novel and works with entire satisfaction. It consists of a set of fans or propellers located in the main leading to the filters and connected to a shaft and gearing which, in turn, operates the pump. The amount applied can be regulated by the stroke of the pump and the size of the plunger. The average amount applied during the past 19 years was 0.91 grain per gallon or about 132 pounds per million gallons of water treated. At no time has any of the sulphate of alumina which is used as a coagulant been found in the filtered water, although large samples of the water are frequently tested.

The average alkalinity of the unfiltered water was 21.3, while that of the filtered water was 15.1 parts per million, showing that 6.2 parts per million are used by one grain of sulphate of alumina per gallon of water treated. It has not been necessary to use lime or soda-ash at any time, as the alkalinity has always been sufficient to decompose more sulphate of alumina than is required to properly coagulate the water.

Shortly after this plant was placed in operation an attempt was made to use sulphate of iron and lime as the coagulant, but the results were not satisfactory.

The filter building originally contained 8 high-type Jewell gravity filters, but in 1908 four additional filters were installed, so that at the present time the plant contains 12 units, each having a normal capacity of 520,000 gallons per day.

Each filter is 16 feet inside diameter, the total sand area being 2117 square feet or about one-twentieth of an acre.

The filter bed consists of 5 inches of graded gravel and 25 inches of sand. The mechanical analysis of the sand shows the effective size to be 0.62 mm., and the uniformity coefficient 1.12.

The filter tanks, which are of 2¾ inch cypress, show some decay in a few places; from time to time it has become necessary to replace some of the bands.

The strainers in the filters are known as "C-J," manufactured by the New York Continental Jewell Filtration Company. It has been found necessary to repair some of these strainers about every 6 years. They are repaired by removing the old rivets and gauze, and replacing the gauze and rivets, the men at the plant doing this work. There are 702 strainers in each filter, spaced on 6-inch centers.

The filters are equipped with loss of head gauges and Weston automatic effluent controllers.

The water to be filtered is first treated with a solution of sulphate of alumina. The sulphate of alumina is dissolved in two solution tanks, each having a capacity of 1500 gallons. This solution is prepared by weight and it has been found that a strong solution will react more quickly and better than a weak one.

The amount of solution applied depends upon the condition of the water and the temperature. In warm weather the action is quicker and less solution is required than when the temperature of the water is low. The average amount of sulphate of alumina used during the 12 years before the sterilizing reagent was used was 1.11 grains per gallon, while during the 8 years in which the sterilizing reagent has been used the average was 0.65 grain per gallon, showing a saving of 41.5 per cent. The minimum amount of sulphate of alumina which will form any coagulation is about 0.25 grain per gallons; if less is used no coagulation is visible.

After treatment with sulphate of alumina the water passes to the coagulation basin under each filter, and is there retained from 20 to 30 minutes. In passing through the coagulation basin about 30 per cent of the suspended matter is removed.

The water then passes to the top of the sand. After passing through the sand it is discharged into the filtered water reservoir directly under the filters. This reservoir has a capacity of 225,000 gallons and is connected with another covered reservoir of about 2,000,000 gallons capacity. From these reservoirs the water flows to the consumers. The reservoirs are of such capacity that it is possible to operate the filters at a uniform rate at all times.

When the filters become "clogged," it is necessary to wash them by pumping filtered water up through the beds, the amount used being about 10 gallons per square foot of sand surface per minute. During the washing the mechanical rakes are operated. The average amount of wash water used during the past 20 years was 2.54 per cent of the water filtered. A filter is out of operation about 7 minutes per wash.

During the first few years after the plant was in operation it was customary to "sterilize" the sand beds every six months. This was done by placing about 300 pounds of soda-ash on the surface of the sand bed and then introducing steam through the strainer system until the beds boiled for one hour. While this treatment cleaned the sand grains, it was found that it would be at least a week before the bacterial efficiency would be satisfactory, therefore the "sterilization" has not been used during the past 17 years.

When this plant was first placed in operation bacterial examination of water was in its infancy. There were no chemical or bacterial tests made during 1900. Previous to 1904, chemical and bacterial tests covering periods of a week were made several times each year. Since that time an extensive laboratory has been maintained and daily chemical and bacterial tests are made. Since the daily chemical and bacterial tests have been made it has been possible to keep the plant under control at all times and the results obtained show a better efficiency and more uniform results.

In determining the bacterial content of the water it has been found that gelatin media at 20°C. for 48 hours is the most satisfactory. In determining the bacterial count all plates are made in duplicate and the average count reported. A large percentage of the filtered water and city tap plates are incubated for 72 hours and remain sterile at the end of this period. All sterile plates are recorded as containing one bacterium per cubic centimeter.

Several times the filter beds have become "seeded" and at such times the agar bacterial plates did not indicate the true conditions.

During the entire 20 years the filtered water has always been free from color and turbidity.

The extreme maximum bacterial content of the unfiltered water always follows the copper sulphate treatments of the water in the sedimentation basins.

The extreme maximum bacterial content of the filtered water comes when the beds are "seeded" and does not mean that this number of bacteria are passing the filters from the unfiltered water.

All these maximum bacterial counts are included in the averages. The results show that the filters remove 98.37 per cent of the bacteria.

The average results in table 1, modified to show the effect of sterilization in 1911-1918, show that the bacteria were reduced 97.52 per cent by sterilization; 25.06 per cent by sedimentation; 98.37 per cent by filtration and 33.34 per cent in passing through the filtered water reservoirs and the city mains.

The total reduction for the system from creek to city tap was 99.77 per cent.

The agar counts on creek water were 74.64 per cent less than gelatin; aerated 50.14 per cent; settled 37.98 per cent; filtered 72.47 per cent and city tap 85.14 per cent. These results show that agar media incubated for 24 hours at 37½°C. prevent the growth of a large number of organisms when compared with the gelatin counts incubated for 48 hours at 20°C.

Aeration did not remove any of the B. coli, but sterilization removed 83.07 per cent; sedimentation 31.44 per cent; filtration

95.80 per cent and the passage through the filtered water reservoir and mains 100.0 per cent.

Although thousands of samples of the city tap water have been examined for B. coli, its presence has never been discovered.

The average turbidity of the creek water is higher than at the fountain, as the aerator is not operated at times of high turbidity.

The sedimentation basins remove 65.16 per cent of the turbidity, while the filters remove 100.0 per cent of the turbidity that passes the basins.

Aeration and sterilization do not remove any of the color. Sedimentation and storage, exposed to air and light, removed 43.21 per cent; while the filters removed 100.0 per cent of the color that passed the basins.

TABLE 3

Average bacteria per cubic centimeter, special tests, creek, aerated and sterilized, settled, filtered and city tap water, gelatin incubated 48 hours at 20°C.; agar incubated 24 hours at 37½°C.

YEAR	CREEK		AERATED		SETTLED		FILTERED		TAP	
	Gelatin	Agar	Gelatin	Agar	Gelatin	Agar	Gelatin	Agar	Gelatin	Agar
1911	2,440	1,610	543	364	1,702	1,666	14.0	5.0	18.0	11.0
1912	15,033	3,533	1,578	580	1,180	274	148.0	14.0	133.0	7.0
1913	1,250	533	133	73	106	73	28.0	26.0	14.0	9.0
1914	641	248	88	45	55	25	7.0	0.8	10.0	0.1
1915	2,117	1,137	254	159	166	111	5.0	4.0	10.0	10.0
1916	758	500	137	79	868	538	15.0	10.0	8.0	6.0
1917	6,458	2,165	162	112	203	51	2.0	0.5	1.0	0.7
1918	10,066	108	73	64	145	83	2.0	0.4	2.0	0.5
Average.	4,845	1,229	371	185	553	343	27.6	7.6	37.0	5.5

Table 2 shows that a very small amount of sulphate of alumina is required to remove the color and turbidity, while the amount of water used in washing the filters is very reasonable.

During the seven years (1892-1898) before the filter plant was in operation, there were 769 cases of typhoid fever, with 104 deaths, the death rate being 58.1 per 100,000 population.

During the twenty years (1899-1918) that the filter plant has been in operation there have been 1582 cases of typhoid fever, with 170 deaths, the average death rate being 22.6 per 100,000 population, making a reduction of 61.1 per cent in the death rate.

The average typhoid fever death rate during the 12 years that only sulphate of alumina was used was 28.5 per 100,000 population; compared with the rate before filtration this is a reduction of 50.9 per cent in the rate.

During the 8 years in which the sterilizing reagent has been used with the sulphate of alumina, the typhoid fever death rate has been 13.8 per 100,000 population. Compared with the rate when sulphate of alumina was used, this is a reduction of 51.6 per cent, and if compared with the rate before filtration was introduced the reduction would be 76.3 per cent in the typhoid fever death rate.

The entire improvement in the typhoid fever death rate is not due to the improvement in the public water supply. It is not the intention to imply that all typhoid fever is due to impure water. There are many other means of conveying this disease. The proper purification of water will only prevent typhoid fever previously due to impure water.

The data in table 1 do not show that there is any connection between the bacteria and B. coli in the filtered water and the typhoid fever death rate.

A study of the results will show that the operation of the York water purification plant has been very successful. Charles W. Graff has been superintendent of the filter plant and resident chemist and bacteriologist since 1902. The officers of the York Water Company are: Charles Kurtz, president; Samuel Small, Jr., vice-president; Smyser Williams, secretary; J. J. Frick, treasurer, and Edgar P. Kable, general manager.